

# **An A-Train Integrated Aerosol, Cloud, and Radiation Data Product**

**P.I.: B. A. Wielicki, NASA LaRC**

**Co-Is:** David Winker, Thomas Charlock, Paul Stackhouse, Patrick Minnis, Kuan-man Xu, NASA LaRC, Graeme Stephens, Colorado State University, William Collins, NCAR, Norman Loeb, Hampton University

**Project hypothesis : Provide an A-Train Integrated Aerosol, Cloud, and Radiation Data Product**

## **Objectives & deliverables:**

- Provide the most highly integrated data set for cloud/aerosol/radiation including CERES fluxes and 4-D radiative assimilation, MODIS cloud and aerosol, CALIPSO cloud and aerosol profiles, Cloudsat cloud profiles, MATCH aerosol assimilation, GEOS 4.0.3 dynamical assimilation.
- Subset the data along the CALIPSO/CloudSat groundtrack to dramatically reduce data volume and still allow global data.
- Provide both L2 and L3 (gridded) merged data products
- Evolve with increasing complexity and completeness with time. Walk then run.
- Help to greatly advance the science community ability to attack aerosol/cloud/radiation research that drives the energy cycle directly, and indirectly the hydrology cycle.



**Technical approach and/or methods** (can be supported or explained with 2-3 additional figure pages):

- Build on CERES data fusion experience and start
- Take advantage of existing links on  
CERES/CALIPSO/CloudSat/GEOS-4/MATCH/Cloud Objects/CRMs/MMFs
- Dramatically reduce CERES/MODIS/CALIPSO/CloudSat data volumes by focusing on cloud, aerosol, radiative flux profiles along lidar/radar ground track and 64-km swath centered on it.
- Provide subset data sets to science community
- Produce more accurate vertical flux profiles along A-train ground track (active/passive/model) especially for multi-layer clouds and polar clouds
- Provide L2, L3 grid, and L3 cloud object versions of the integrated cloud/aerosol/flux profiles.

# CERES: Integrated Data for Radiation/Cloud/Aerosol

- 2 to 10 times *ERBE* accuracy: moving from  $5 \text{ W/m}^2$  toward  $1 \text{ W/m}^2$
- TOA, surface and atmosphere fluxes
- A radiative 4-D assimilation: integration of surface/cloud/aerosol/atmosphere constrained to TOA flux

## Input Data

CERES Crosstrack Broadband  
CERES Hemispheric Scan ADMs  
MODIS Cloud/Aerosol/Snow&Ice  
Microwave Sea-Ice  
MATCH Aerosol Assimilation  
GEOS 4-D Assimilation Weather  
(fixed climate assimilation system)  
Geostationary 3-hourly Cloud  
Consistent Intercalibration

## Output Data

ERBE-Like TOA Fluxes (20km fov, 2.5 deg grid)

CERES Instantaneous TOA/Sfc/Atmosphere Flux  
- 20km field of view (SSF, CRS products)  
- 1 degree grid (SFC, FSW products)  
- Fluxes, cloud & aerosol properties

CERES Time Averaged TOA/Sfc/Atmosphere  
- 3-hourly, daily, monthly  
- 1 degree grid (SRBAVG, AVG, ZAVG products)  
- Fluxes, cloud and aerosol properties

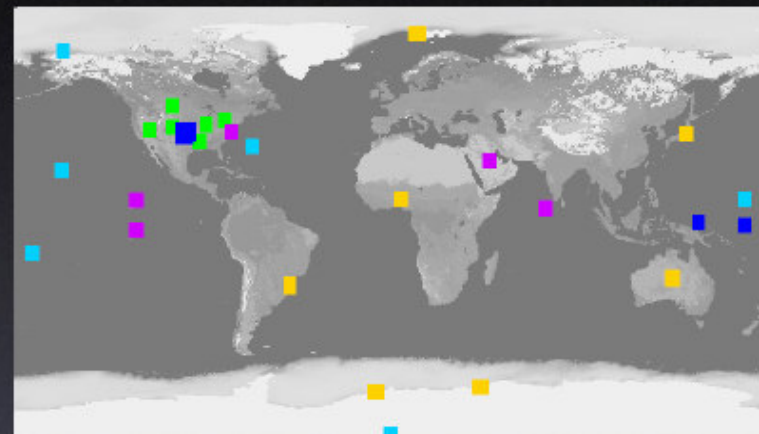
***CERES provides NPOESS a 4-D radiative flux assimilation: merged Surface/aerosol/cloud/atmosphere/radiation from surface to TOA.***

# New Terra CERES CRS Data Product

## Instantaneous Match Surface Flux Accuracy

Tested against 40 BSRN, ARM  
SURFRAD, COVE surface sites

Surface Flux	Bias (24 hr Average)*	Aerosol Forcing (24 hr)	Sigma (24 hr Average)*	Samples
SW Down All-sky	3	-	27	3900
LW Down All-sky	- 5	-	22	7700
SW Down Clear-sky	0	- 8	8	1600
LW Down Clear-sky	- 9	2	15	800

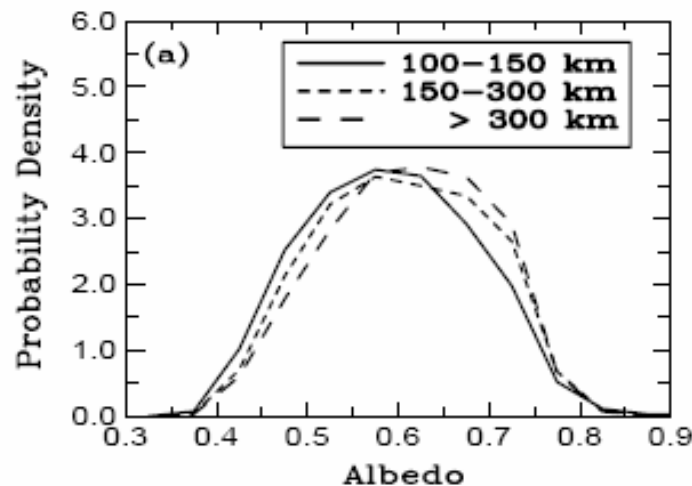


- Surface Data Averaged over 30 minutes
- Uses closest CERES 20-km field of view
- MODIS clear-sky aerosols
- NCAR MATCH aerosol assimilation of MODIS for cloudy sky aerosol
- GSFC GEOS-4 assimilation atmosphere
- New gamma distribution Fu-Liou model
- No surface data used in satellite retrieval

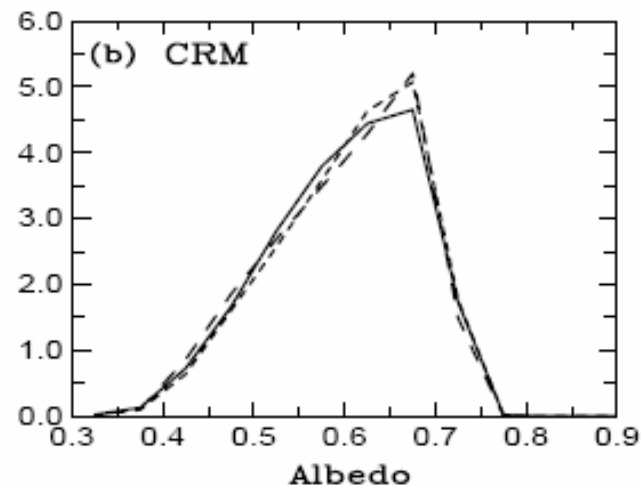
\* SW fluxes are scaled to 24-hour average insolation (1/3 typical Terra 10:30 am values)  
LW fluxes include both daytime and night-time validation results

# Large Deep Convective Cloud Systems: $H_t > 10\text{km}$ , $\tau > 10$ , Fraction = 1, Diameter $> 100\text{km}$ March, 1998, 25N to 25S

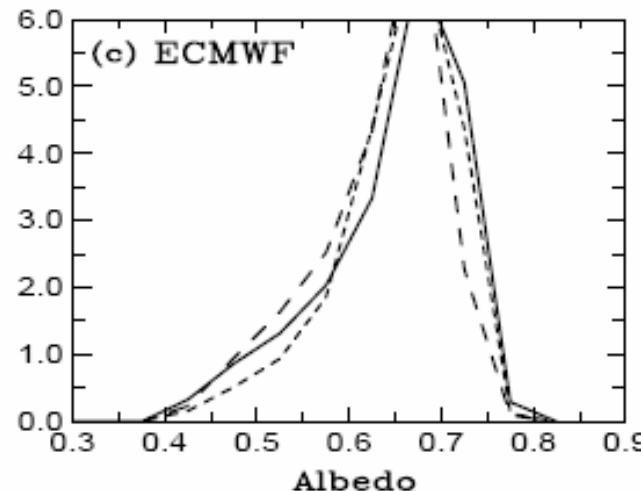
## CERES Observations



## Cloud Resolving Model (2km 2-D)



ECMWF initial conditions,  
advective tendencies  
Cloud Object Data  
available at:  
<http://cloud-object.larc.nasa.gov/>



ECMWF  
(50 km 3-D)

Xu et al., 2005

**Data set needs** (particularly large data sets – include potential sizes):

- CERES Merged aerosol/cloud/fluxes (5 levels): 5GB/day, 5TB/3yrs
- MODIS L1 radiances: CERES subsample at 2km, 19 channels, 25GB/day, 25TB/3yrs
- MODIS Aerosol Data Product, 3GB/day, 3TB/3yrs
- CALIPSO lidar aerosol/cloud vertical profiles (y-z), 3GB/day, 3TB/3yrs
- CALIPSO 128m visible imager (1km swath) 0.1GB/day, 0.1TB/3yrs
- CloudSat radar cloud vertical profiles (y-z) 0.6GB/day, 0.6TB/3yrs
- GEOS 4.0.3 interpolated to CERES fovs <0.1GB/day, <0.1TB/3yrs
- MATCH (NCAR) aerosol assimilation using MODIS and CALIPSO aerosols
- MODIS L1 full resolution 64km subset 6GB/day, 6TB/3yrs
- Total Input Data Volume (most at LaRC DAAC) 50GB/day, 50TB/3yrs

**Project outputs** (project results that may be made available to the NEWS team for subsequent use – include potential size/resource requirements):

### **Subsets at 1km and 64km swaths along A-train lidar/radar groundtrack**

***Data Products are subset along lidar/radar ground track to (1/64km) swaths.***

- CERES CRS L2 flux profiles subset along lidar/radar groundtrack, 50 MB/day, 50GB/3yrs
- MODIS L1 radiance subset used by CERES, 650/10 MB/day, 650/10 GB/3yrs
- MODIS MOD 04 L2 Aerosol subsets, 100 MB/day, 100GB/3yrs
- GEOS 4.0.3 atmosphere state profiles interpolated to CERES fovs, 15MB/day, 15GB/3yrs
- MATCH aerosol assimilation of MODIS/CALIPSO interpolated to CERES fovs

***New integrated A-train vertical profiles of aerosols/cloud/radiation***

- L2 Cloud/Aerosol/Flux profiles(120levels) (200MB/day at 20km res, 800MB/day at 5km)  
(integrates CERES/MODIS/CALIPSO/CloudSat/GEOS/MATCH along A-train)
- L3 monthly (1 deg lat / 30 deg lon) gridded data (90MBmonth)
- L3 annual mean (1 deg lat 30 deg lon: 90MB/year), (1 deg lat 5 deg lon: 540MB/year)
- L3 Cloud object sets of aerosol/cloud/radiative flux profiles: similar to gridded volume
- Total Output Product Data Volume (all on hard disk data pool) 2GB/day, 2TB/3yrs

**Potential collaborations** (with NSIT, other NEWS projects, etc.) :

- NSIT activities for global energy/water budget perspective
- Cloud/aerosol/energy studies (L'Ecuyer, Leung, Soden, Roads, Betts, Curry)
- A-train water integrated product (Fetzer)
- Land/energy studies (Denning, Peters-Lidard)

**Important outside linkages/resources** (outside the NEWS team) :

- CERES (Wielicki, P.I.)
- CALIPSO (Winker, Co-I)
- CloudSat (Stephens, Co-I)
- MATCH NCAR Aerosol Assimilation (Collins, Co-I)
- Cloud Modeling, GCSS, MMF (Xu, Co-I)
- GEOS 4.0.3/ GEOS 5 (Wu through CERES-GEOS link)
- GEWEX Radiative Flux Assessment (Wielicki, Stackhouse)
- Aerosol Direct and Indirect Research (Loeb, Co-I)

## **Expected contribution to the NEWS objective:**

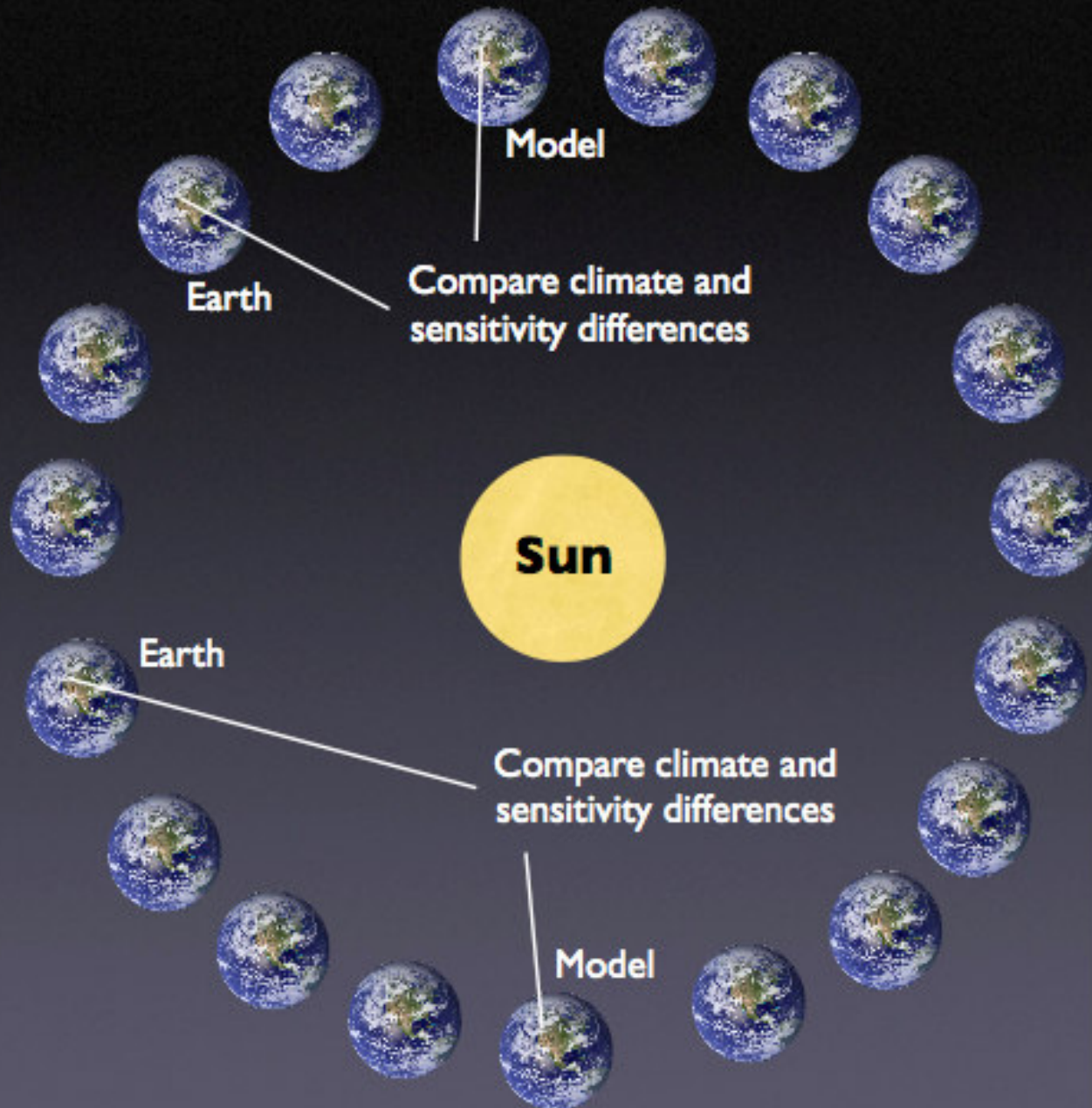
- Improved 4-D radiative assimilation by adding CALIPSO/CloudSat vertical profiles to CERES radiative flux profiles: surface, in atmosphere, to TOA
- Provide cloud type subsets of A-train data matched to GEOS-4 atmospheric state data. Allows improved cause/effect tests of cloud modeling.
- These data products make it much easier for the broader science community to take advantage of the A-train cloud/aerosol/radiation data
- Data products to assess accuracy of MODIS cloud products, CERES surface/atm fluxes especially for polar clouds.
- Data products to assess the effect of cloud contamination on aerosol Direct Radiative Effect
- Data products to improve estimates of aerosol Indirect Effects

## **Issues, needs, and concerns** (to be discussed in breakouts, teaming discussions, etc.):

- GEOS-4 vs GEOS-5 vs ECMWF
- How near real-time is needed? 1 week? 1 month? 6 months?
- Subsetting of full res MODIS L1 and L2 radiance/cloud/aerosol for 64km swath at GSFC
- Support to GEWEX Radiative Flux/Cloud/Aerosol/Precip Assessments: started post NRA
- Need new approaches to determine climate model prediction uncertainty and climate observation requirements/priorities (by variable/time scale/space scale/accuracy)

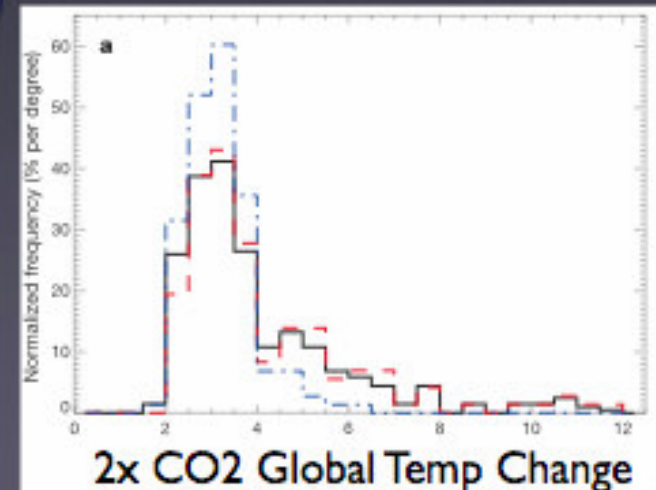
# Backup Figures

# 60,000 Earth-Like Planets

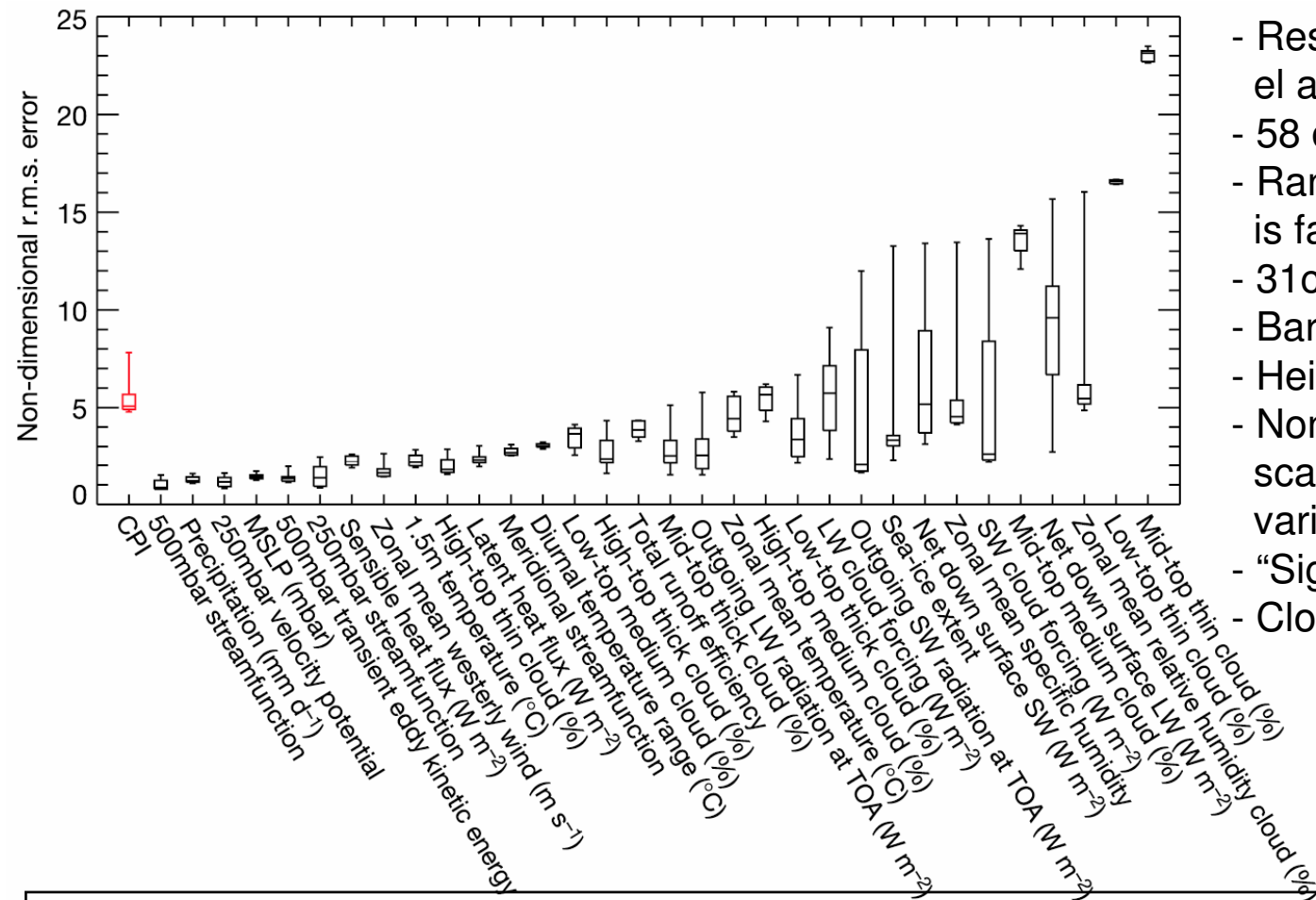


**climateprediction.net:**  
**constant known physics**  
**vary uncertain physics**  
**Run for normal CO<sub>2</sub>**  
**Run for doubled CO<sub>2</sub>**

*Stainforth et al.,  
2005, Nature*



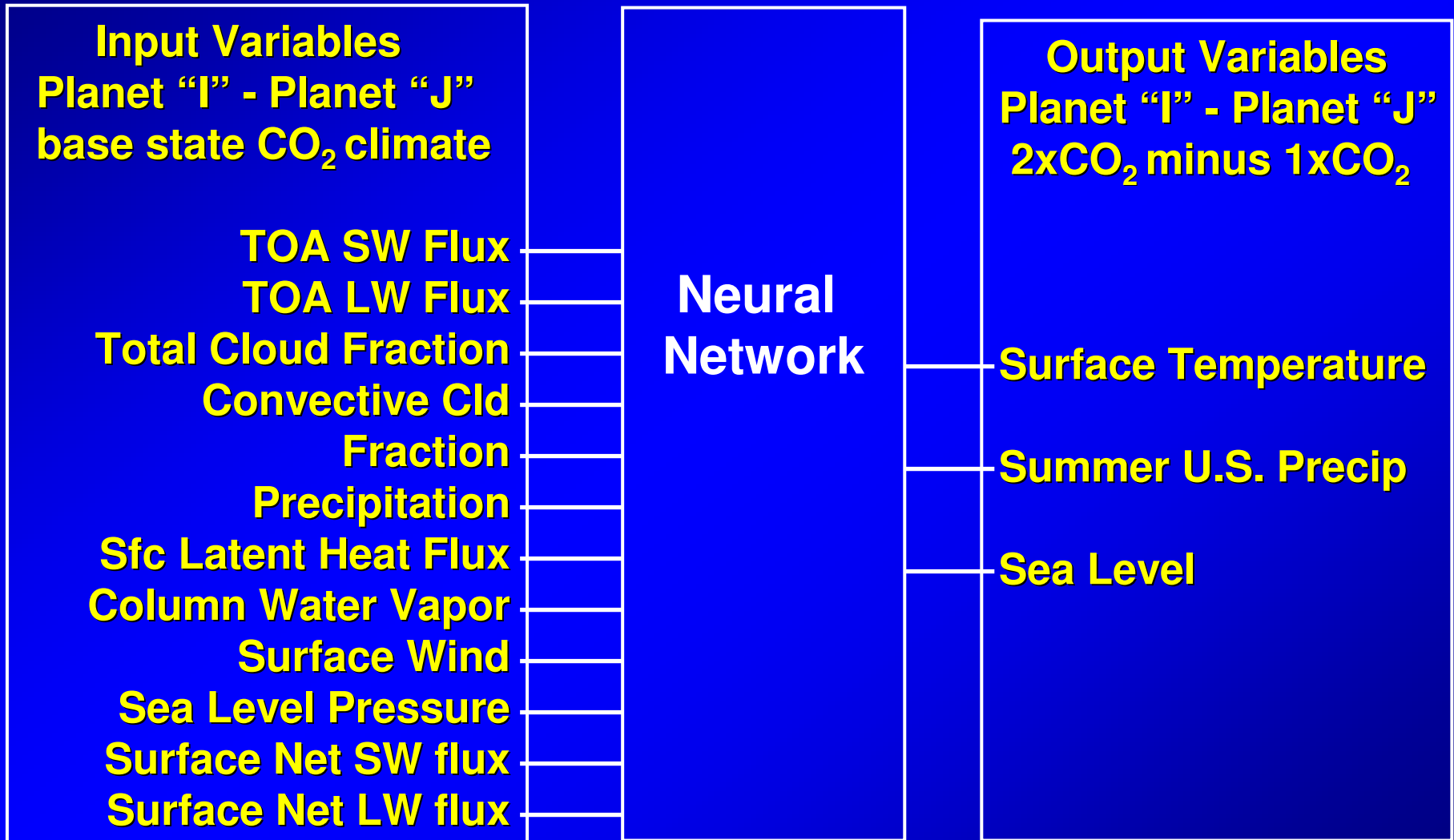
# Amount of change for a factor of 6 in climate model sensitivity, by climate variable: clouds dominate



- Results from Murphy et al., Nature, Aug 04
- 58 different climate models
- Range of climate sens. is factor of 5
- 31 climate metrics (plot)
- Bars are 25 to 75th pctile
- Height of line is min to max
- Non-dimensional scaling is to interannual variability (noise)
- “Signal to noise”
- Clouds/radiation dominate

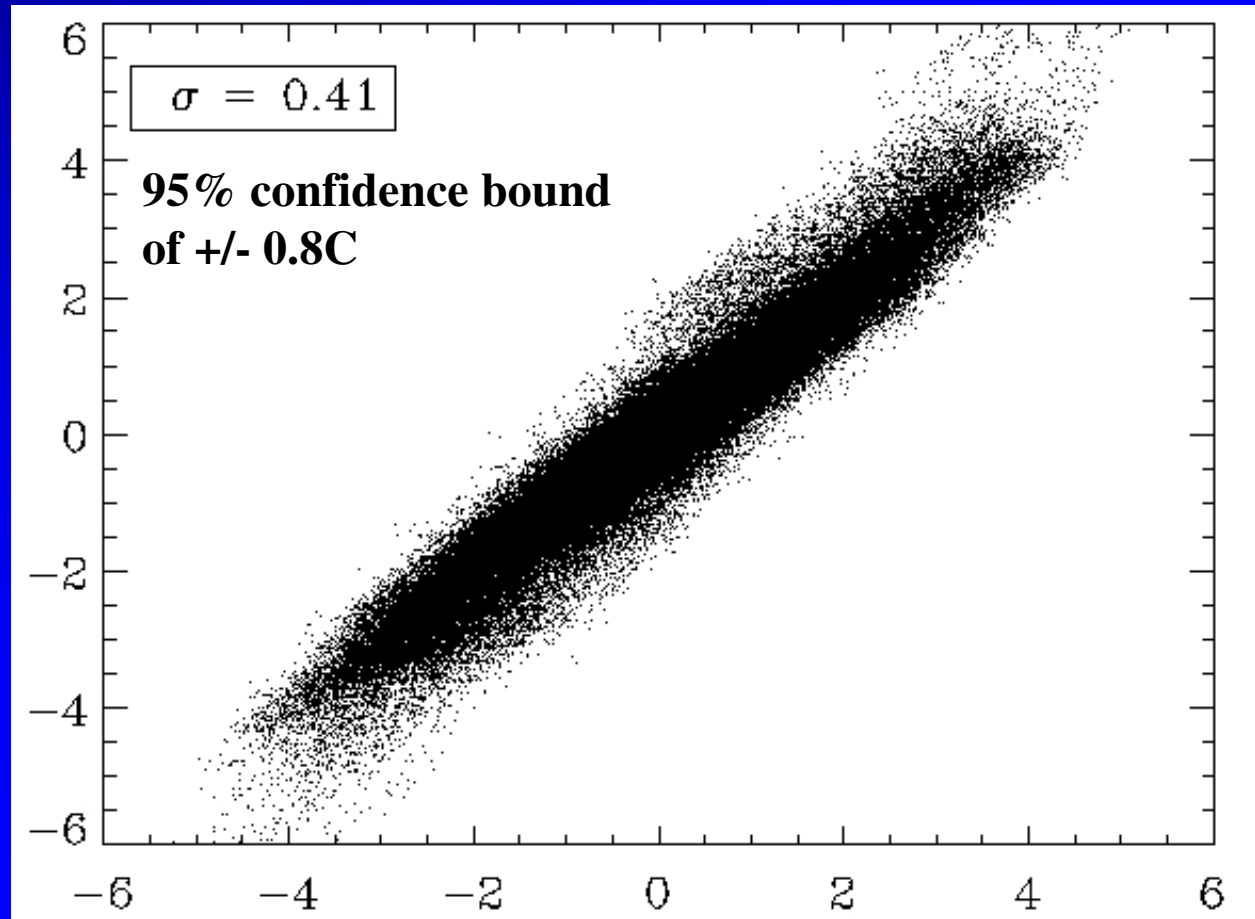
***We critically need more rigorous ways to quantify climate observation requirements as a function of variable/time/space scale. Perturbed Physics Ensemble approach is the first opportunity to attack this fundamental problem.***

# Neural Net Structure



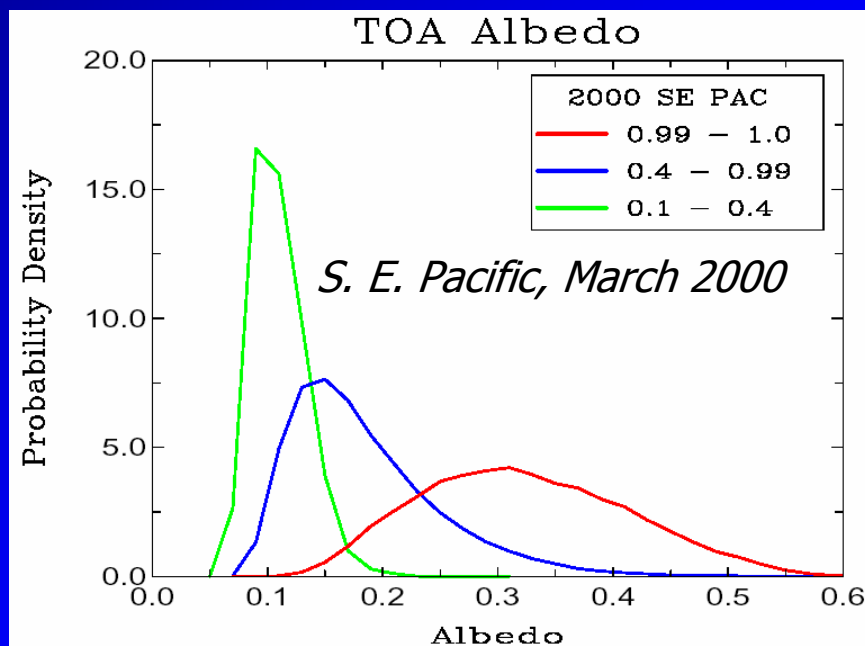
# Neural Net Prediction of Climate Sensitivity

Planet "I" minus Planet "J"  
Doubled CO<sub>2</sub> Global Temp Change

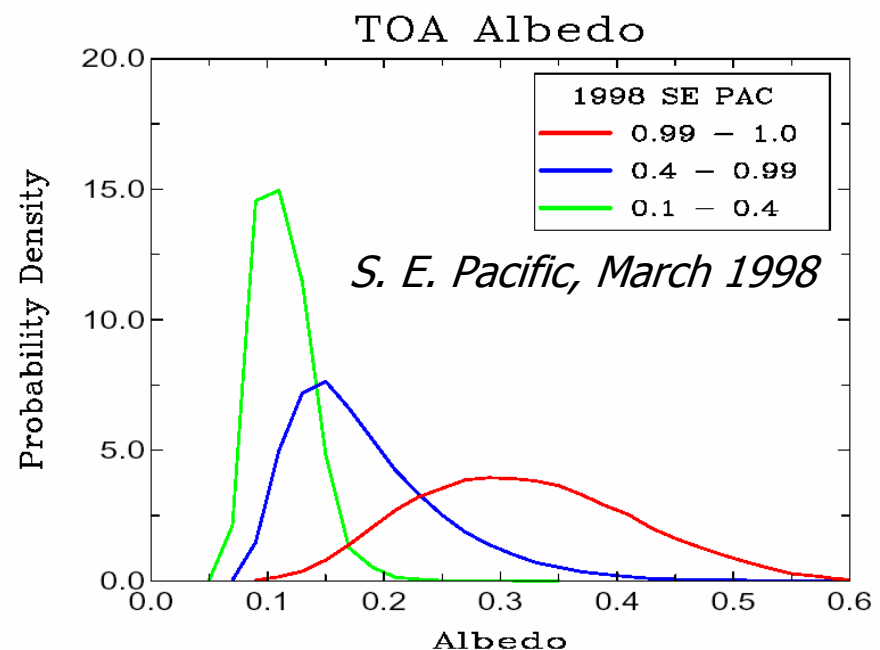


**Neural Net Prediction: Doubled CO<sub>2</sub> Global Temp Change  
(uses Planet I and J normal CO<sub>2</sub> climate only)**

# Boundary Layer Cloud Systems: Observed CERES TOA Albedo Pdfs for March, 2000 La Nina vs March, 1998 El Nino

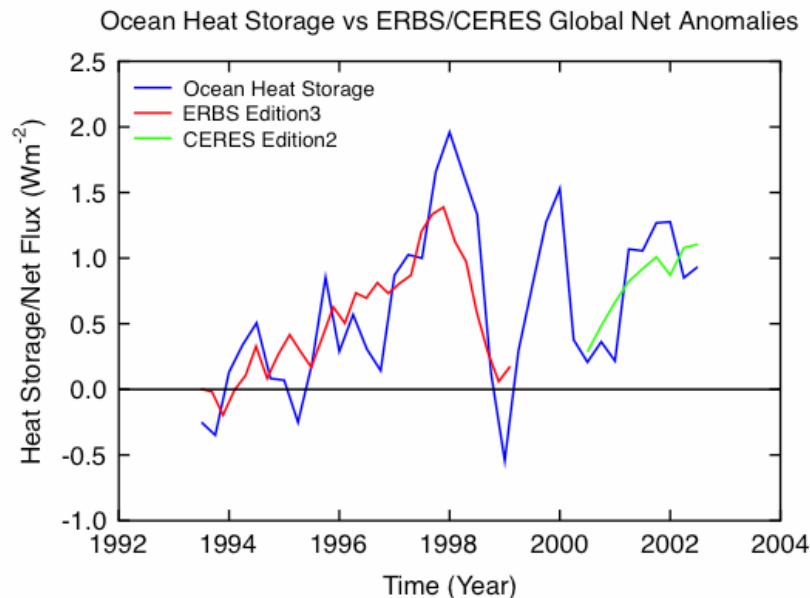


*No apparent difference in the  
S.E. Pacific, even though  
the Walker Cell strength reduced,  
Hadley cell strengthened...*



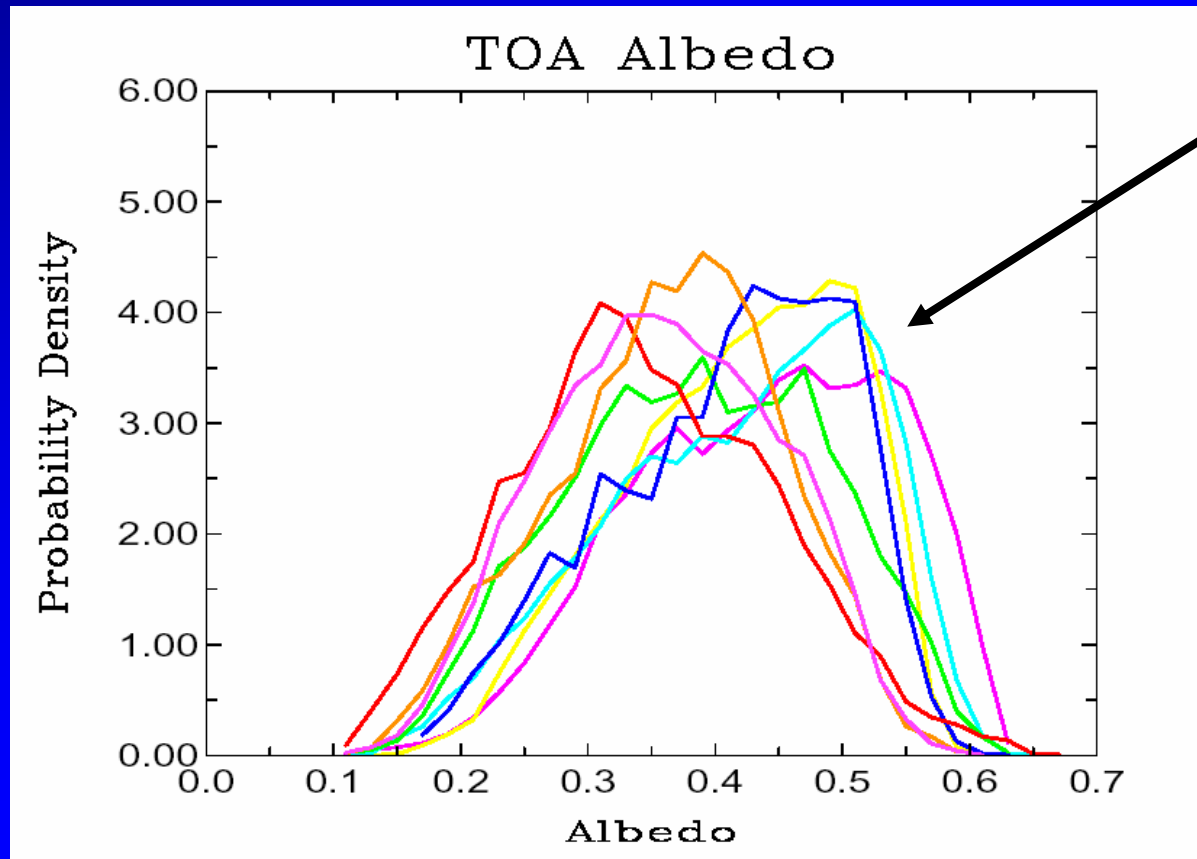
*Suggests stable properties by  
cloud type: next step to quantify  
how stable.... 1 Wm<sup>2</sup> ? 0.1 Wm<sup>2</sup>?*

# Global Radiation and Ocean Heat Storage: What does it mean?



- Climate atmos. noise only  $0.3 \text{ Wm}^{-2}$
- Ocean/Rad diff =  $0.4 \text{ Wm}^{-2} 1\sigma$   
= ocean spatial sampling noise
- ERBS cavity radiometer gain change =  $0.1\%$  or  $0.2 \text{ Wm}^{-2}$
- $1.5 \text{ Wm}^{-2}$  variations larger than expected
- IPCC forcing =  $0.6 \text{ Wm}^{-2}/\text{decade}$
- All other heat storage mechanisms are smaller by factor of 10 or more
- Aerosol/greenhouse forcing changes small except Pinatubo in 91-93
- Large changes = variations in net cloud radiative forcing
- Not clear if ocean  $\Rightarrow$  cloud or cloud  $\Rightarrow$  ocean
- Non-equilibrium link of ocean/cloud must be unscrambled in model/data

# Overcast Boundary Layer Cloud Systems : Observed CERES Cloud Objects for March, 1998



Sample individual pdfs  
for just 8 of the stratus  
cloud systems  
(CERES SSF TOA albedo)

**Weather:** can we predict  
why they vary? SST?  
wind shear? boundary  
layer height?

**Climate:** can we predict  
the ensemble mean vs  
change in SST, wind  
shear, etc? Feedbacks  
in partial derivatives